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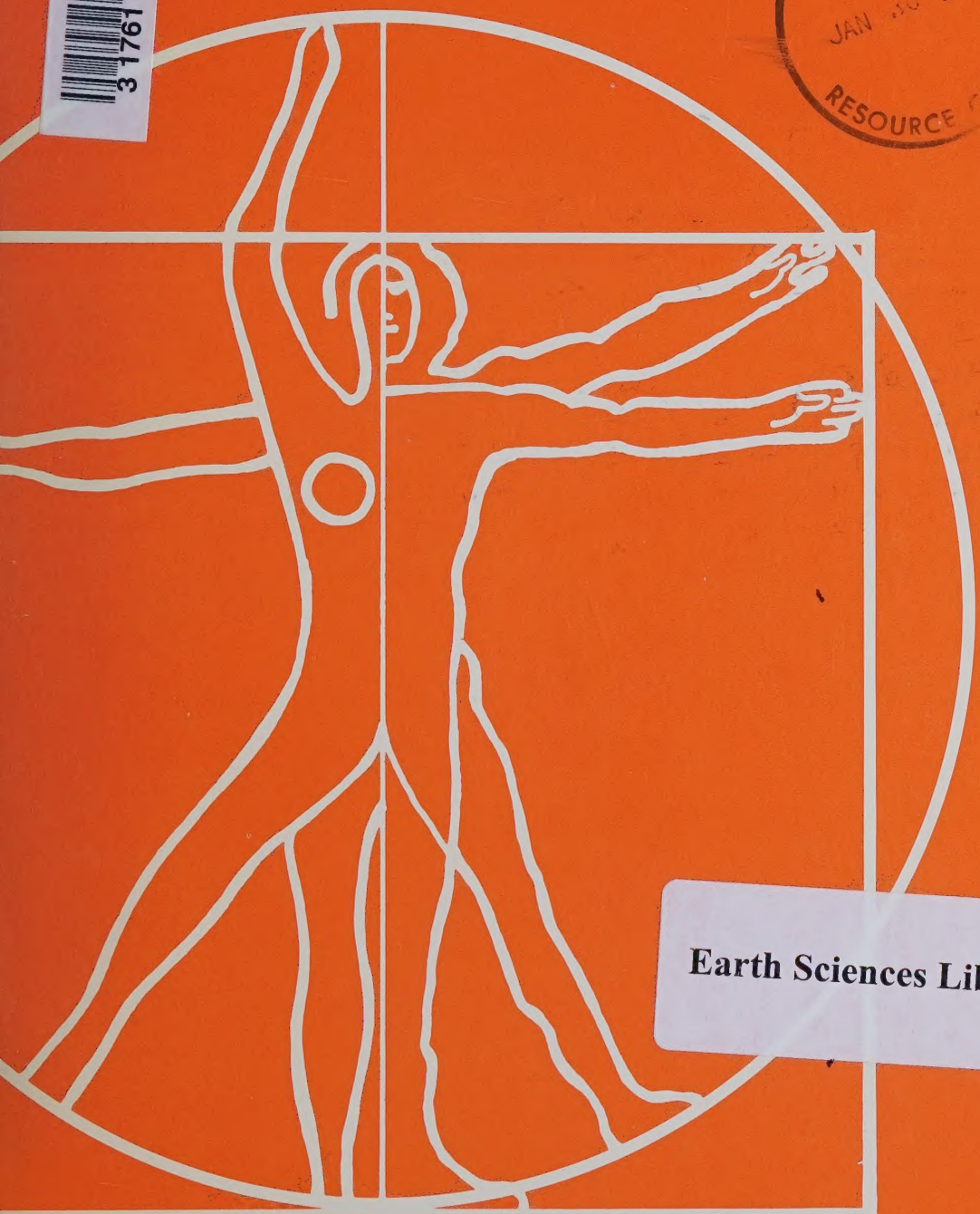

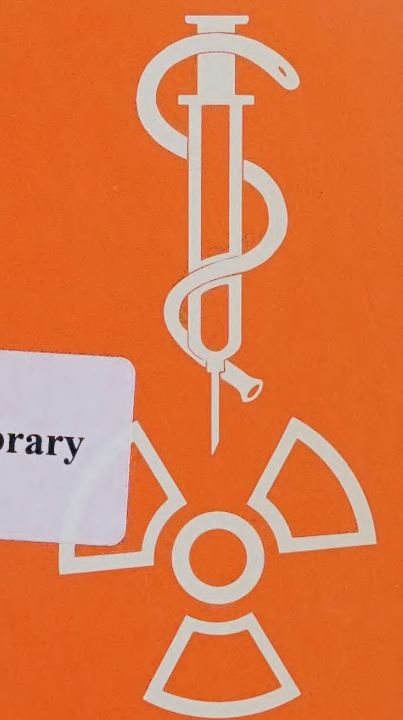

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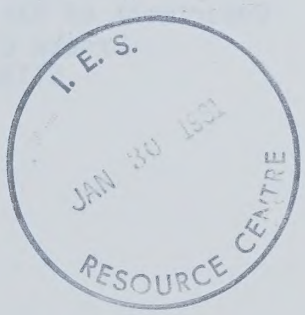
REPORT ON THE SURVEY OF RADIO FREQUENCY HEATERS

Environmental Health Directorate
Health Protection Branch



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ABSTRACT

Radio-frequency (RF) heaters at various plants throughout Canada were surveyed during 1979. The heaters were used most frequently for sealing plastic, some however were utilized for glueing wood pieces. The majority of the devices operated at a frequency of 27.12 MHz; others operated at various frequencies between 5 and 100 MHz. The output power ranged between 1 and 90 kW.

The survey identified types of devices, and provided information on design and operating characteristics. Data on the intensity of the electric and magnetic fields in the vicinity of the RF heaters were collected and analyzed. The material presented constitutes part of the data base for guidelines and regulations to protect workers from potentially harmful exposures to RF radiation.

SOMMAIRE

Les réchauds haute-fréquence (H.F.) de diverses usines dans tout le Canada firent l'objet d'une étude au cours de 1979. Ils servaient pour la plupart à sceller le plastique mais quelques-uns étaient destinés au collage de pièces de bois. La majeure partie de ces appareils fonctionnent à 27.12 MHz; d'autres utilisent diverses fréquences situées entre 5 et 100 MHz. Leur puissance de sortie varie entre 1 et 90 kW.

L'étude a défini les types de dispositifs et fourni des renseignements sur leur conception et leurs caractéristiques de fonctionnement. Elle a recueilli et analysé des données sur l'intensité des champs électriques et magnétiques au voisinage des réchauds H.F. Le texte qui suit constitue une partie de la base des données dont il faut disposer pour élaborer des lignes directrices et des règlements visant à protéger les travailleurs contre les effets nocifs éventuels de l'exposition aux radiations H.F.

PREFACE

The Radiation Protection Bureau conducts surveys of various devices to investigate potential radiation hazards to personnel, and to develop and recommend safety guidelines and regulations as necessary under the Radiation Emitting Devices Act.

During 1979, surveys of RF heat sealers were conducted throughout the country, in cooperation with the Federal-Provincial Subcommittee on Radiation Surveillance and the following departments: Alberta Department of Labour, British Columbia Department of Health, British Columbia Ministry of Labour, Ontario Ministry of Labour, Ontario Department of Communications and Quebec Ministry of Municipal Affairs and Environment. Among the many individuals from the above Departments who contributed to the surveys, the following deserve a special mention: Dr. M.W. Greene, British Columbia Department of Health, Dr. A.M. Muc, Ontario Ministry of Labour, and Mr. J.M. Wetherill, Alberta Department of Labour.

Special appreciation is due to the Narda Microwave Corporation, Plainview, New York for loaning some of the instrumentation used during one of the surveys.

The report was prepared by Dr. M.A. Stuchly, M.H. Repacholi, D. Lecuyer, and R. Mann and reviewed by Drs. E.G. Letourneau, P.J. Waight and W. Zuk of the Radiation Protection Bureau, Dr. J.A. Orpin of the Bureau of Medical Devices, Health and Welfare Canada, H. Bassen, Dr. Z.R. Glaser, P. Ruggera and M. Swicord of the Bureau of Radiological Health, U.S. Department of Health, Education and Welfare, and Dr. D.L. Conover of the National Institute for Occupational Safety and Health, U.S. Department of Health, Education and Welfare.

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INTRODUCTION

Radio frequency (RF) heaters are used in a variety of plants to seal plastic materials and to glue wood. Sealing or glueing takes place as a result of heating induced by the applied RF field. Most heaters operate at a frequency of 27.12 MHz, which has been allocated by the Radio Act of Canada for industrial, scientific and medical uses (ISM). There are also heaters operating at two other ISM frequencies, namely 13.56 and 40.68 MHz, as well as many older devices operating at unallocated frequencies between 5 and 100 MHz. The output power of the devices ranges between 1 and 90 kW. Processing is accomplished between parallel plate electrodes forming a capacitor. The shape of the applicator (electrodes), also called dies, is compatible with the shape of the treated material. A typical operation cycle includes about 2-5 seconds with the RF power on, followed by 3 to 30 seconds with the power off.

The relatively high output power of the devices and use of unshielded electrodes in many of them can produce relatively high RF radiation leakage in their vicinity. High intensity RF radiation is known to cause numerous biological effects in experimental animals and uncontrolled exposure to human beings may be harmful to their health [1].

The objective of the surveys of RF heaters was to identify the types of devices on the market, to gather information regarding their design, contruction and use, and to determine the intensity of the RF fields in the occupied areas in the vicinity of these devices. This information was obtained to determine if safe use guidelines or device regulations are necessary to protect the workers from potentially harmful exposure.

From the 22 locations visited, 82 devices were evaluated. A list of the plants and the device models surveyed is given in Appendix A.

INSTRUMENTATION

To determine the exposure to the operator from an RF heater to radio frequency radiation, it is necessary to measure the intensity of both the electric (E) and the magnetic (H) fields. Since the personnel exposure takes place in the near-field [2], the plane wave relationship, $E/H = 377\Omega$, does not apply and both intensities have to be known to evaluate the power deposition in the body of the operator [3]. Whenever the term power density is used in this report, it refers to the equivalent plane-wave power density, which represents what would be the power density of the equivalent plane-wave having the same electric or magnetic field intensity. The particular field intensity is always denoted. The equivalent power density is calculated as

$$W\ (W/m^2) = E^2(V/m) / 377,$$

where E is the electric field intensity (rms value), or

$$W\ (W/m^2) = H^2\ (A/m) \times 377,$$

where H is the magnetic field intensity (rms vlaue).

The following instruments were used during the surveys:

1. E field survey meter, Narda, model 8616, probe model 8644,
   dynamic range: 0.1 mW/cm^2-2 W/cm^2,
   frequency: 10 MHz - 300 MHz,
   calibration accuracy: $\pm$0.5 dB,
   spatial response: isotropic.

2. Electric field sensor, Instruments for Industry,
   model EFS1,
   dynamic range: 1 - 300 V/m
   frequency: 10 kHz - 200 MHz
   calibration accuracy: $\pm$5% (meter scale only)
   spatial response: unidirectional

3. H field survey meter, model 25540, probe model 8635,
   dynamic range: 0.1 - 25 $(A/m)^2$,
   frequency: 10 MHz - 300 MHz,
   calibration accuracy: $\pm$0.5 dB,
   spatial response: isotropic

4. H field survey meter, model 8616, probe models 8631 and 8633

dynamic range: 0.02 mW/cm^2 - 20 mW/cm^2, model 8631
0.1 mW/cm^2 - 100 mW/cm^2, model 8633
frequency: 10 MHz - 300 MHz,
calibration accuracy: ±0.5 dB
spatial response: isotropic

The calibration factors for the probes are:

Probe (Narda)	Frequency (MHz)		
	13.56	27.12	50
Model 8644	1.46	1.24	1.01
Model 8635	1.03	0.98	0.98
Model 8631	.99	.90	.98

These calibration factors apply only to the actual probes used in the survey.

MEASUREMENT PROCEDURE

Measurements in all plants were performed during working hours and under normal operating conditions. Field intensities were measured without the operator in the vicinity of the test position, and with the operator at the normal operating position. One type of RF heater (the sewing machine type) cannot be operated, unless the operator is about 0.5m from the device to depress the foot pedal.

To map the fields in the vicinity of the applicator without the operator (allowing minimal perturbation to the measured field) a tape measure was used to determine the distance within ±0.5 cm. Measurements were taken only at the plane of the applicator, since at this plane maximal intensities were observed.

To determine operator exposure, the probe was located 15 cm from the operator toward the sealer. The operator remained in his normal position closest to the device. This way the highest possible exposure was measured.

Since the E field sensor (EFS-1) has a probe consisting of one dipole and is therefore sensitive only to the field component parallel to it, measurements were taken by rotating the probe in mutually perpendicular directions and the total field was calculated from the three readings using the following equation

$$E = \sqrt{E_x^2 + E_y^2 + E_z^2}$$

where E_x, E_y, E_z are the field intensities in the direction x, y, z, respectively.

The accuracy of measurements was a function of the following factors: the instrument calibration accuracy, the spatial response of the probe, the near-field error of the probe, and the measured field perturbation caused by the meter, the surveyor and in most cases the operator. Overall uncertainty in the measured equivalent power density was estimated as ±3 dB.

DEVICE TYPES AND OPERATION

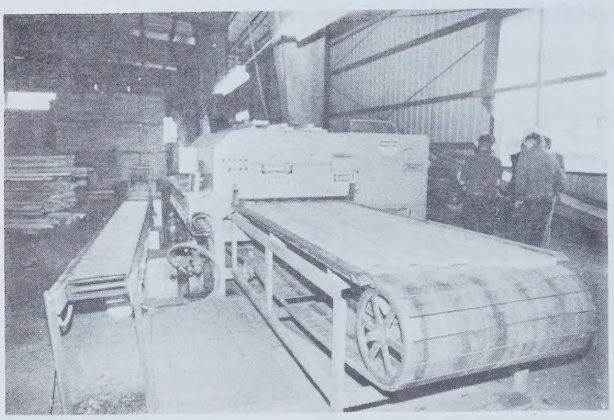
A typical RF heater consists of a cabinet housing the RF generator, power supply and control circuitry, a press, an applicator (a die) and a system to support and move the processed material. Feeding of the material to be heated is accomplished either manually or automatically.

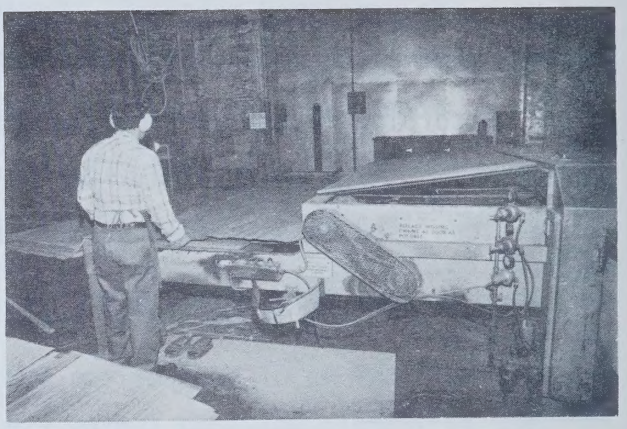
According to the application the heaters surveyed can be divided into two groups:

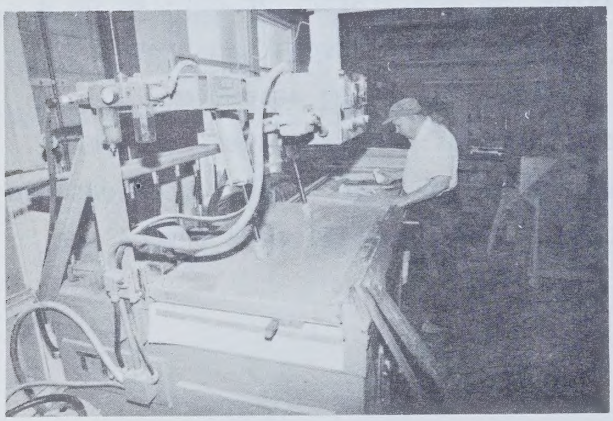
1. devices used to heat-seal plastic material; called RF sealers, and
2. devices used to cure and dry glue, for joining pieces of wood; called edge glue dryers.

Edge Glue Dryers

All edge glue dryers have an applicator consisting of a parallel plate capacitor with rectangular plates of a relatively large surface area. Pieces of wood coated with glue are assembled either inside the applicator, or outside on a tray and then transported to the applicator. Some machines have a two-tray assembly; one tray is under the heater while the other is being assembled. Typically one or two people operate the devices. Out of eight devices surveyed, four were operated by one person, three by two and one by four. The latter case is not typical since the operators were handicapped. A few typical edge dryers are shown in Figure 1.







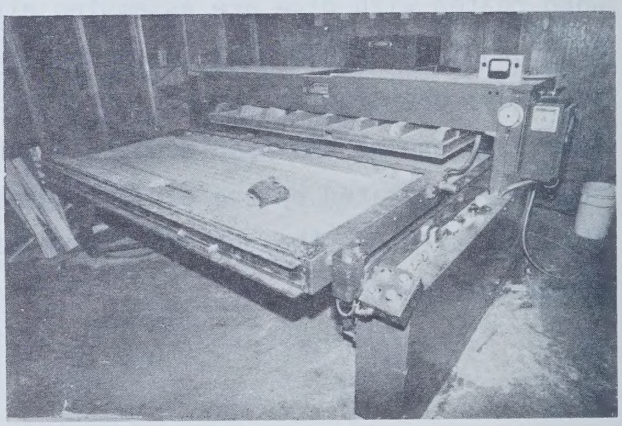


FIG. 1 - Typical Edge-Glue Dryers, Plywood Industry

The operating cycle usually consists of 30 to 60 seconds on, followed by a few minutes when the power is turned off. Table 1 lists the "on/off" durations for some of the devices.

Table 1

Power on/off Durations for Edge Glue Dryers

Device No.	Power "on"	Power "off"
1	5 sec - 10 min	1 - 10 min
2	30 sec	30 sec
3	1 min	1 - 3 min
4	1 min	1 - 3 min
5	30 sec	1 min

RF Sealers

RF sealers used for plastic material display a greater variety of designs that the edge glue dryers. The applicators are capacitor plates, specially shaped to the material processed. Based on general appearance and the material feeding system, RF sealers can be divided into four types:

1. sewing machine,
2. shuttle tray,
3. turntable,
4. pressure sealed applicator.

Sewing Machine

Figure 2 shows a typical sewing machine type RF sealer. Virtually all the operators of this type of machine were women. Typical operation involves placing the processed material inside the die and depressing a pedal to lower the upper plate. The RF power is then turned on, usually following a 2-second delay. After a

preset heating time, the upper plate of the applicator automatically lifts up and the sealed material is removed. The power "on" cycle is generally 2-3 seconds, and the "off" cycle 10 to 60 seconds.

Shuttle Tray

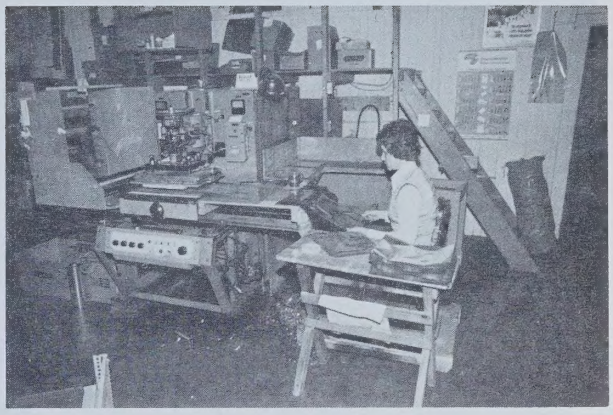
Shuttle tray RF sealers are shown in Figure 3. Typical operation involves arranging the processed material on a tray, when it is then moved manually or automatically to the applicator. The models most frequently encountered have two trays. Sealers in which the processed material is automatically or semi-automatically fed from one or both ends of the applicator, are also classified into this group. Depending on the number of trays, one or two persons operate the machine. Typical durations are 2-3 seconds and 3-30 seconds for the power "on" and power "off", respectively.

Turntable

Figure 4 illustrates turntable sealers. There are usually four or five assembly positions. While one piece of the material is sealed, other pieces are assembled into position. The sealers are operated by two to four persons. Typical operation consists of 2-3 seconds of power followed by 5-10 seconds when the power is turned off.

FIGURE 2(a) Sewing Machine Type Sealer

FIGURE 2(b) Sewing Machine Type Sealer with Operator in Position



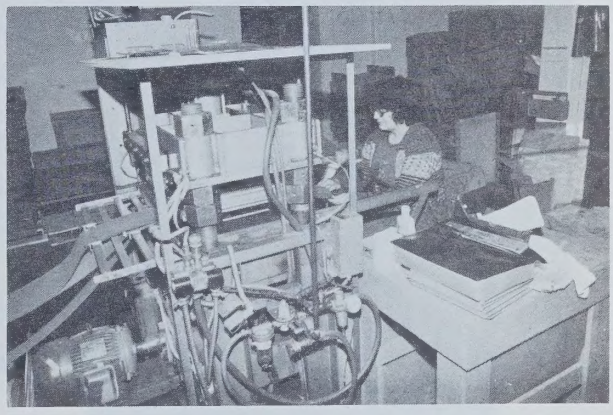
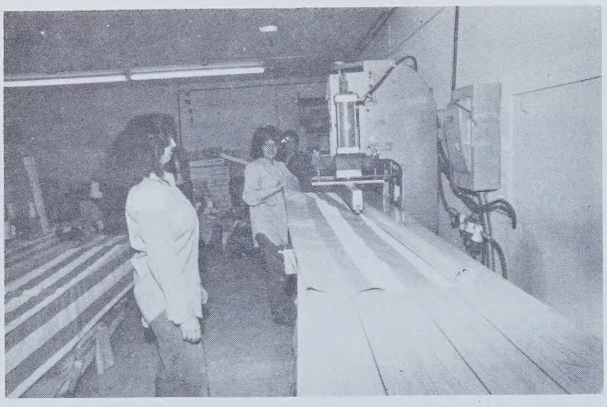
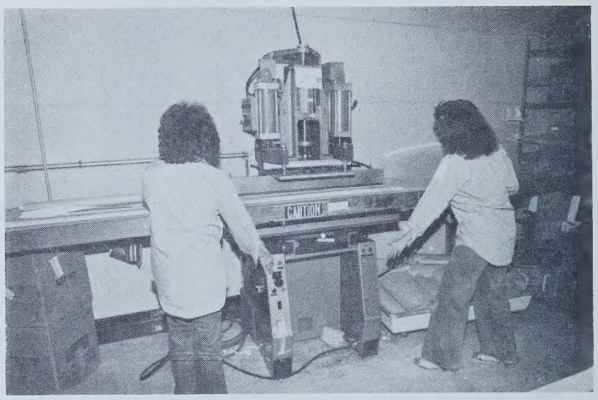
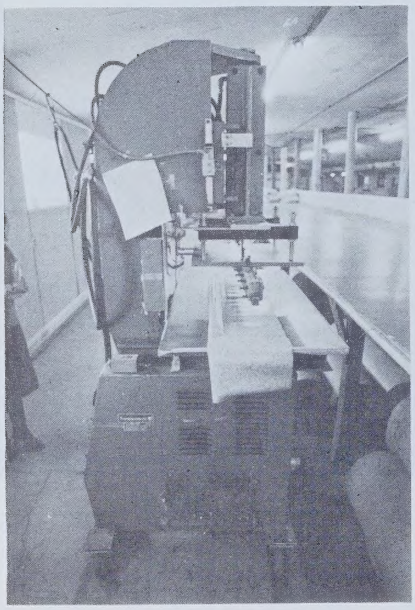


FIGURE 2(c) Typical Sewing Machine Type Sealers with Operator in Position







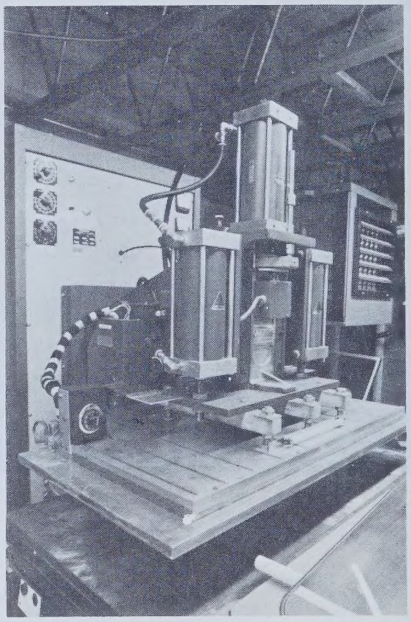


FIGURE 3 Shuttle Tray Type Sealers

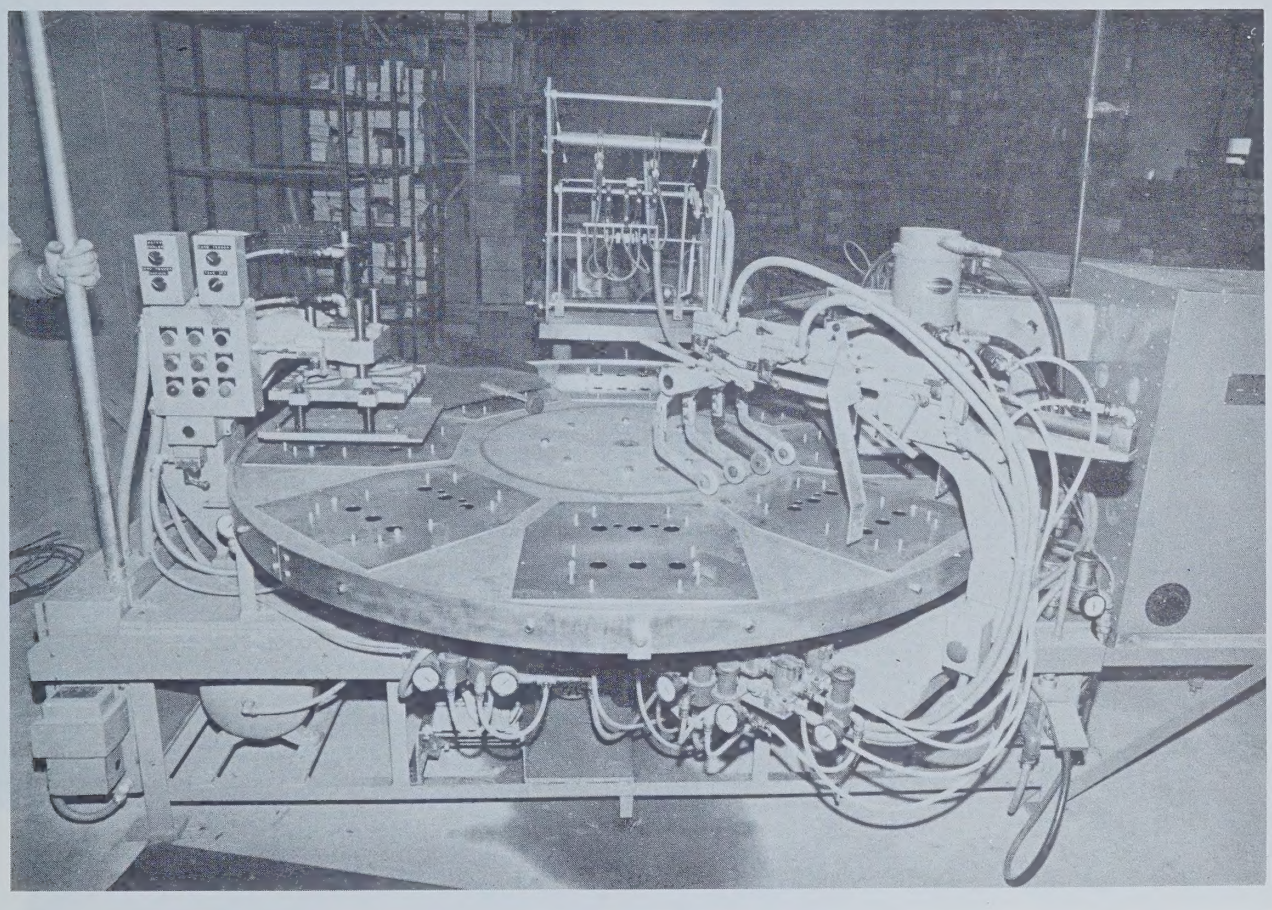


FIGURE 4(a) Turntable Type Sealer

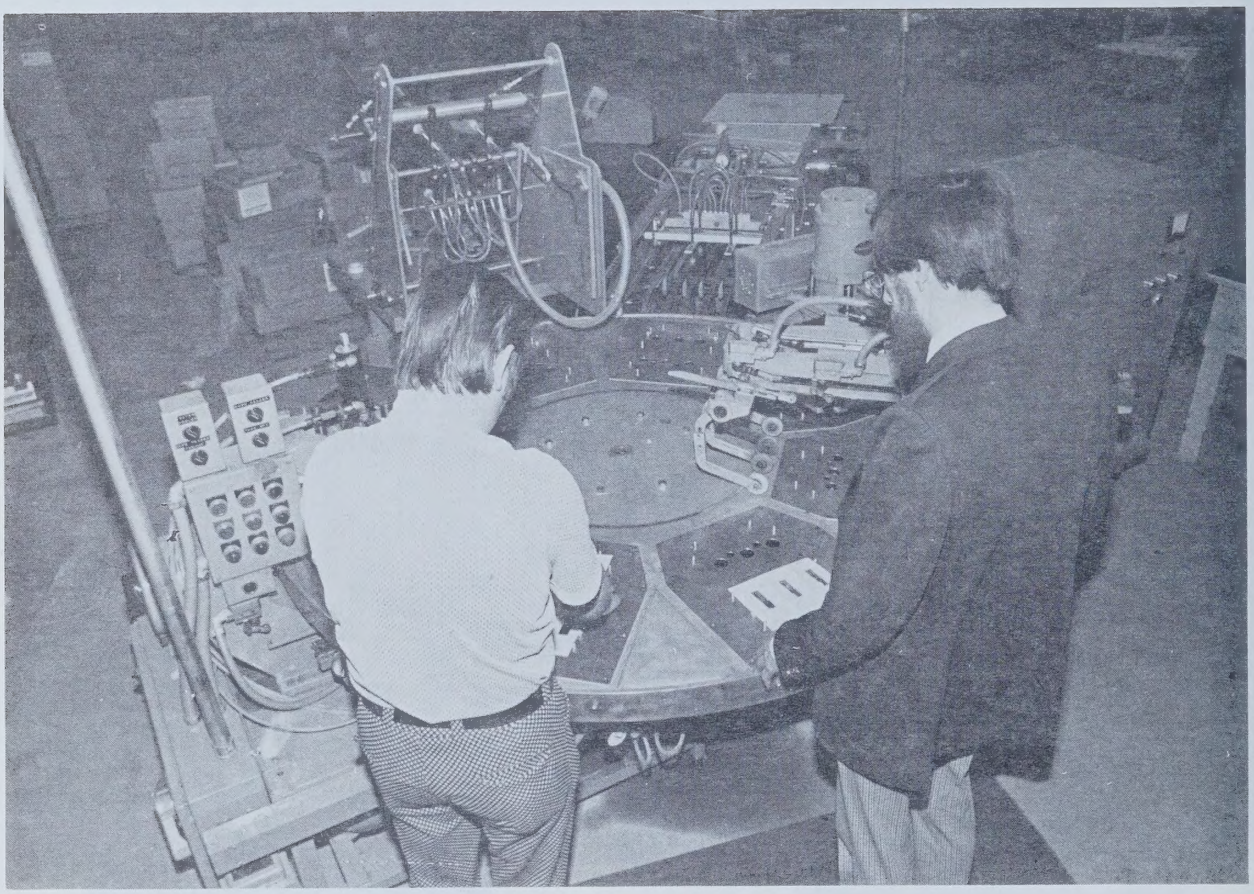
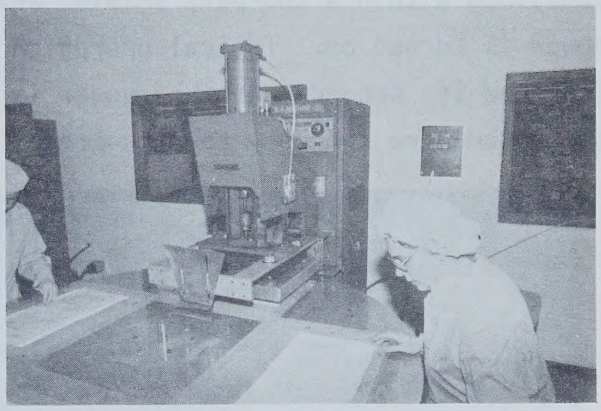
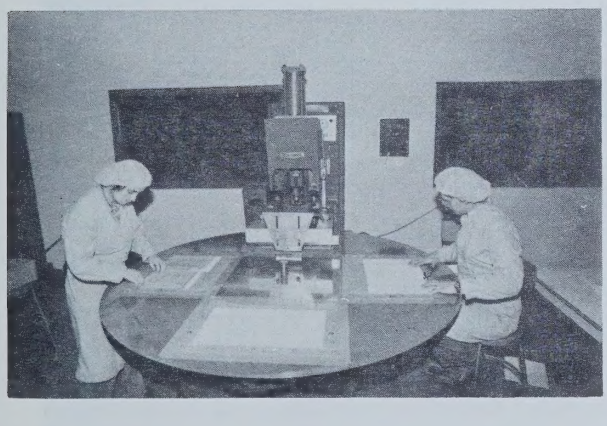


FIGURE 4(b) Turntable Type Sealer with Operators in Position





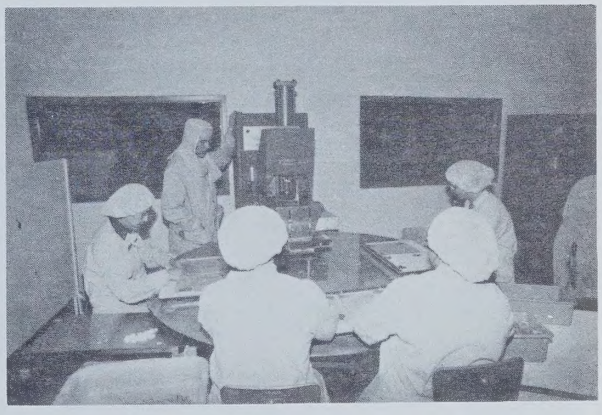


FIGURE 4(c) Turntable Type Sealer

Pressure Sealed Applicator

The specially designed high power RF sealers, having pressure sealed applicators, are shown in Figure 5. These sealers have the active part of the applicator contained within a two-part shield, which is sealed under pressure before the RF power is turned on. Typical operation consists of 12 seconds when the RF power is "on" and 14 seconds when the power is "off". These devices are primarily used in the automotive industry for the production of inner door panels and upholstery.

The operational parameters of RF heaters are summarized in Table 2.

Table 2

Typical Operation Conditions of RF Sealers

Sealer Type	No. Units	Frequency (MHz)	Power (kW)	Power "on" (sec)			Power "off" (sec)		
				Min	Mean	Max	Min	Mean	Max
Sewing Machine	17	20-51	0.75-12	0.5	1.8	30	1	16.7	30
Shuttle Tray	4	25-50	3.0-15	2	3.5	5	5	14.2	20
Turntable	3	27	3.5-6	3	4.1	5	2	3.2	5
Pressure Sealed Applicator	19	13-28	10-90	8	12.3	18	10	14.1	22

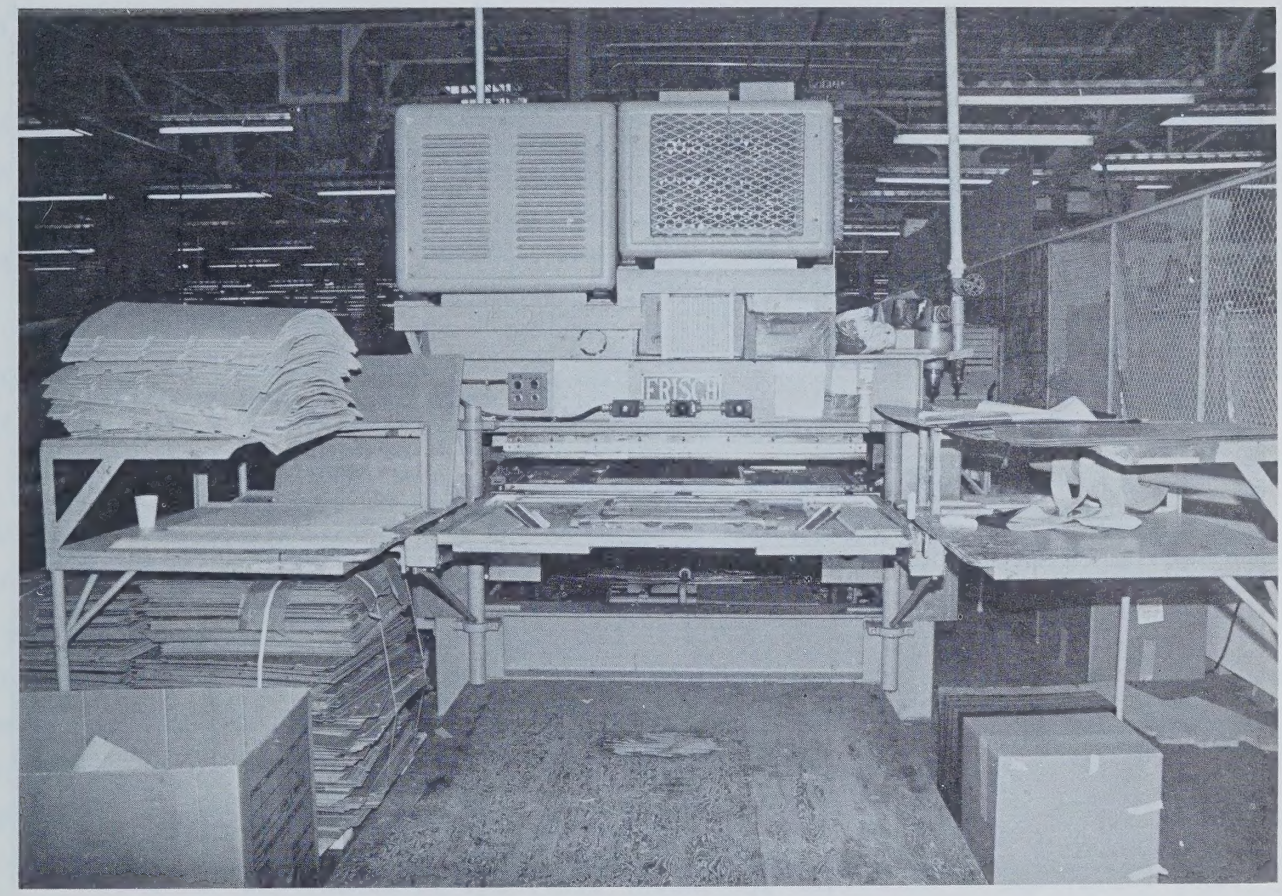


FIGURE 5(a) Pressure Sealed Applicator Type Sealer

FIGURE 5(b) Pressure Sealed Applicator Type Sealer with Operator in Position

SURVEY RESULTS

Fields in the Vicinity of the Applicator

The fields in the vicinity of the applicator were mapped in the horizontal plane. All measurements were performed without the operator in the proximity, except for the sewing machine type sealers where the operator had to remain about 0.5 m from the device to depress the control pedal. Although care was exercised to minimize the perturbations to the field, because of the instrument limitations, a person performed measurements by extending his arm and the probe handle (approx. 30 cm). The data is given in Appendix B. Field mapping was completed for 17 sewing machine units, 4 shuttle tray units and 3 turntable type units. Selection of devices to be surveyed was dictated by preliminary measurements. For example, operators of the sewing machine type units had to be located close to the applicator and would likely be exposed to high intensity fields.

The mean values of the E and H fields at three positions, for all the sewing machine type sealers surveyed, are shown in Figure 6. Figures 7 to 9 show the same data for three typical sealers.

It can be seen from Figure 6 that, for distances from the applicator greater than 5 cm, the equivalent power densities for both E and H fields decrease with distance in an almost linear fashion. (Note that the ordinate scale is (logarithmic). A similar dependence can be observed from Figures 7 to 9 for individual sewing machine sealers. A few exceptions to the trend may be attributed to the presence of perturbations, caused by large metal surfaces in the vicinity of the test location. Also, relatively large uncertainties associated with the measurements should be taken into account.

A similar dependence of the field intensity, expressed in equivalent power density versus distance was observed for the shuttle tray sealer (Figure 10), and the E field for the Turntable sealer (H field not measured, see Table B4).

The differences between the field intensities at various positions are substantial, and can only partly be attributed to the uncertainty in measurements. For most sealers the equivalent power density is substantially greater for the electric field than for the magnetic field.

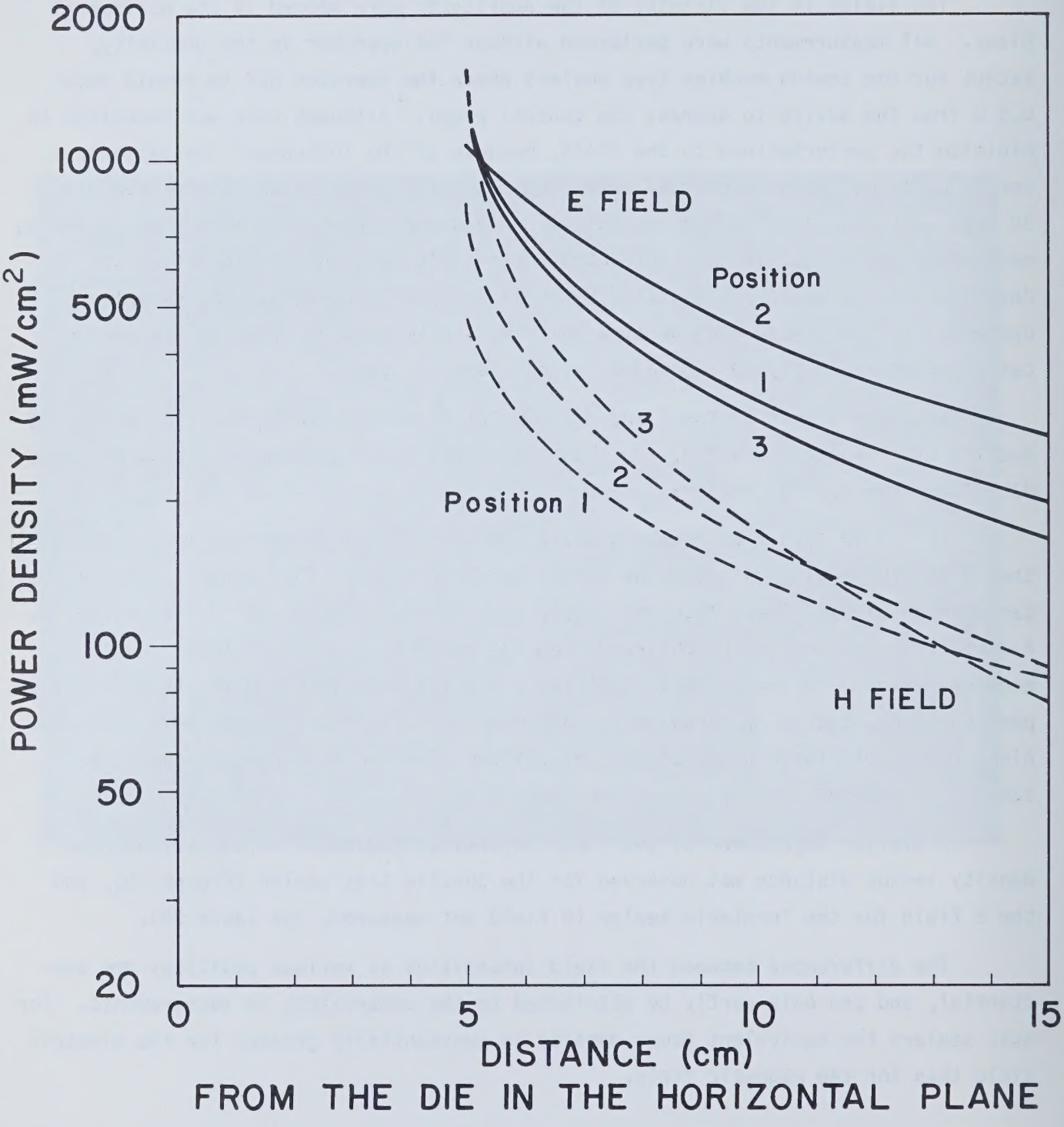


FIGURE 6. Electric and Magnetic Field in the Vicinity of the Sewing Machine Type Sealers; Mean Values for 17 Devices

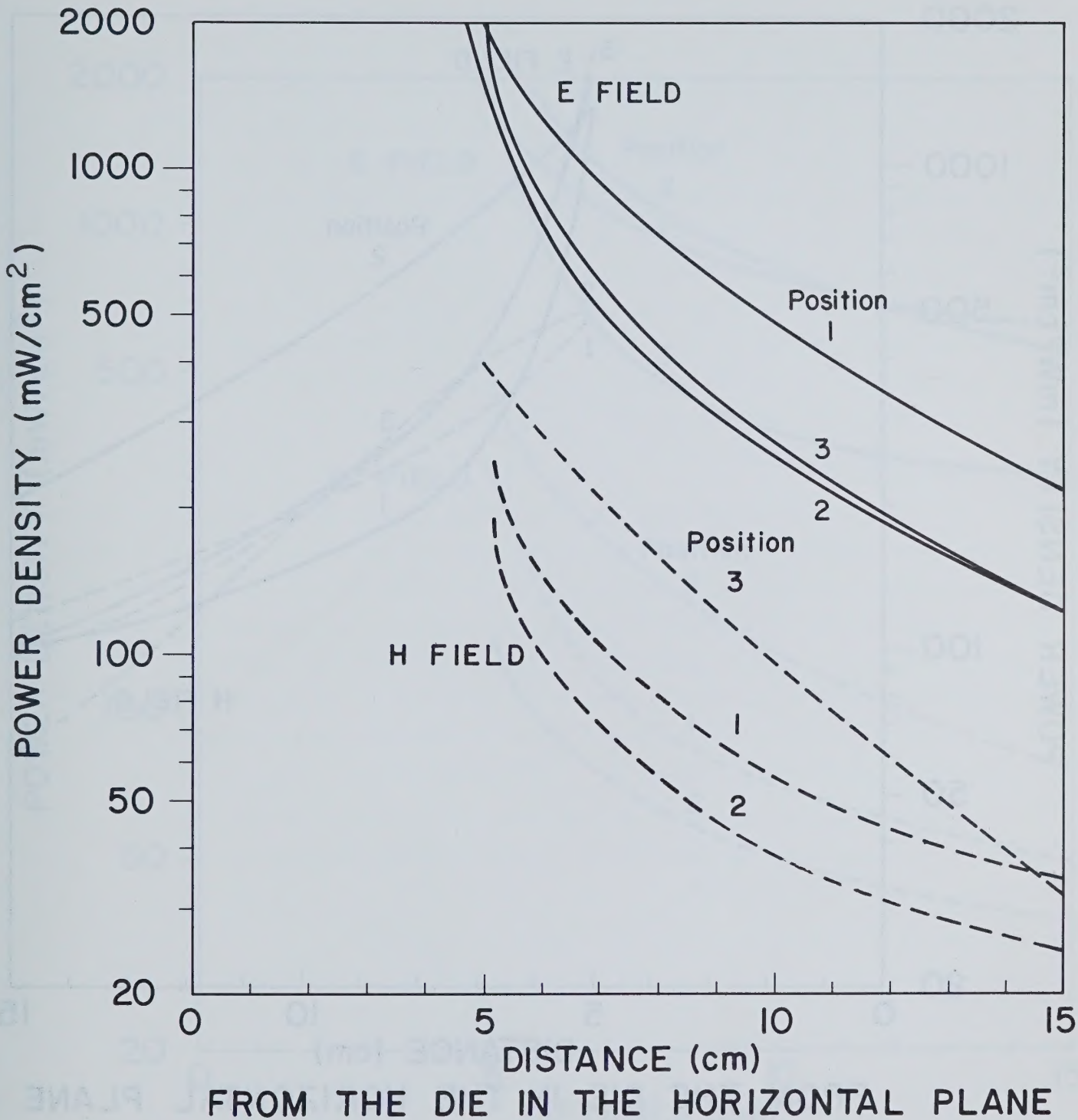


FIGURE 7. Electric and Magnetic Field in the Vicinity of Sewing Machine Sealer Number 32

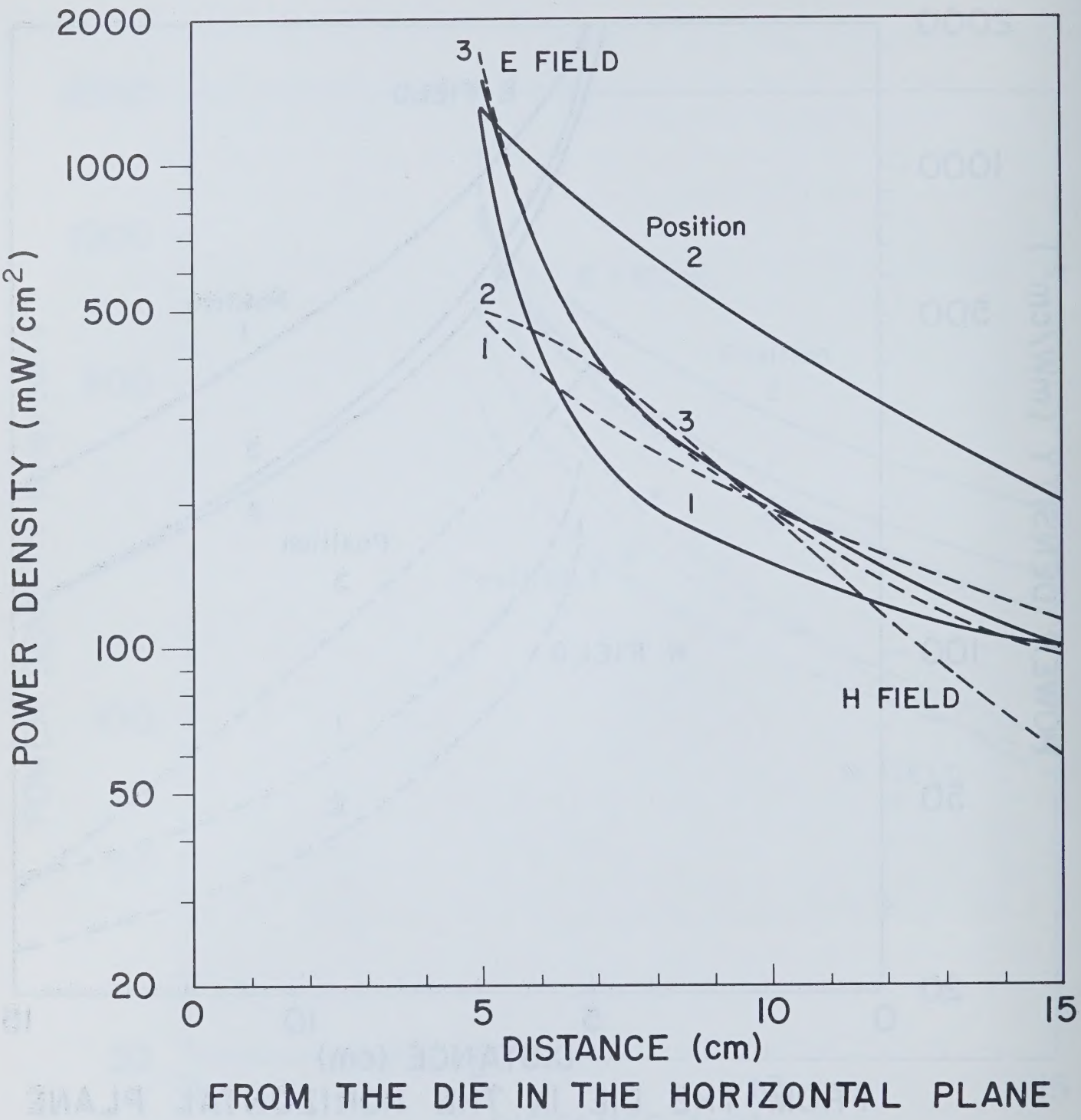


FIGURE 8. Electric and Magnetic Field in the Vicinity of Sewing Machine Sealer Number 37

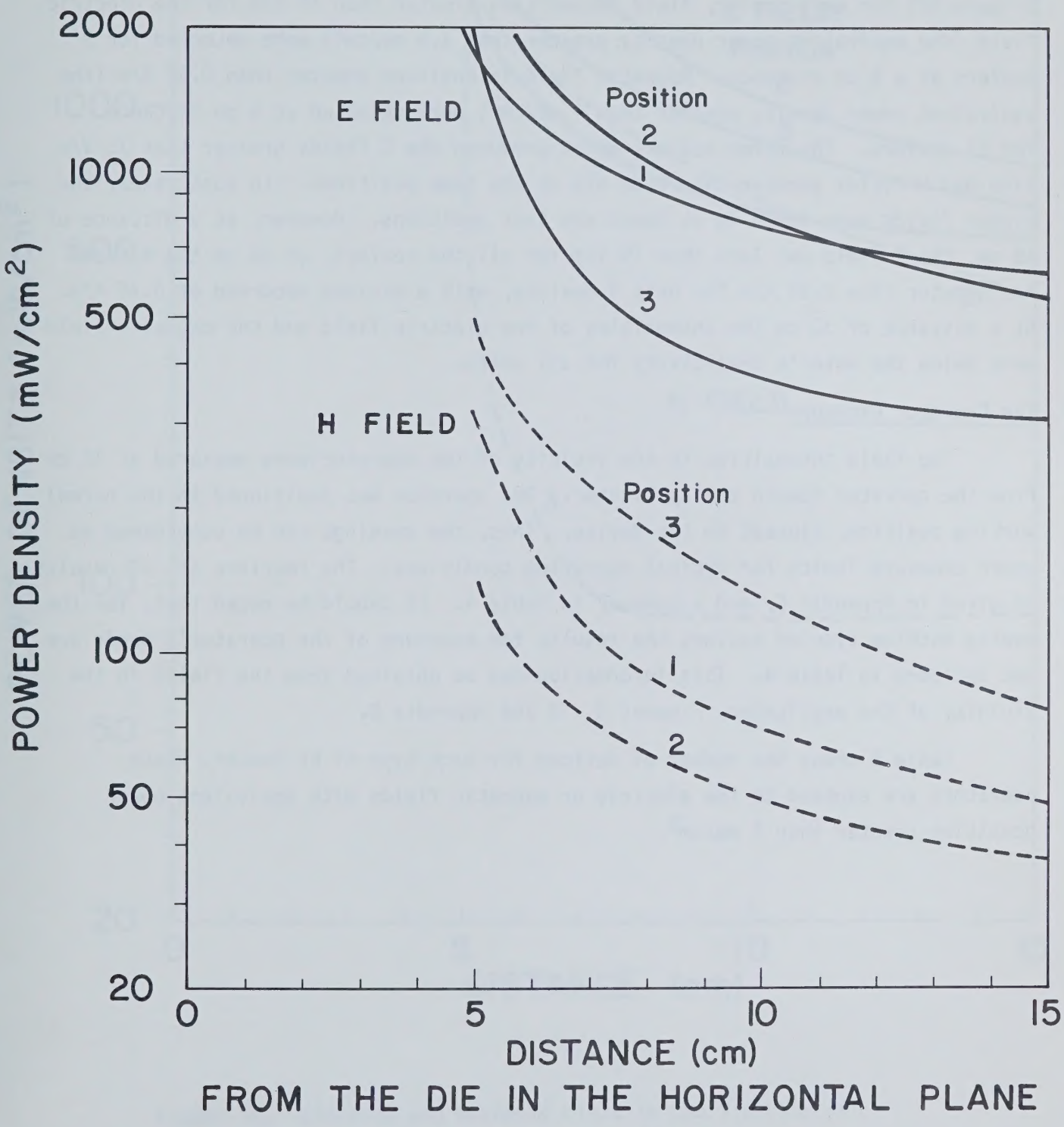


FIGURE 9. Electric and Magnetic Field in the Vicinity of Sewing Machine Sealer Number 55

Only low intensity fields existed, even very close to pressure sealed applicator heaters. From 21 devices surveyed and with measurements taken in 6 positions (Figure B2) for each sealer, field intensities greater than 75 V/m for the electric field (the equivalent power density greater than 1.5 mW/cm^2) were detected for 3 sealers at a 5 cm distance. Magnetic field intensities greater than 0.32 A/m (the equivalent power density greater than 4 mW/cm^2) were detected at 5 cm distance for 12 sealers. The three sealers which produced the E fields greater than 75 V/m also had H fields greater than 0.32 A/m at the same positions. In most cases, the higher fields were found in at least two test positions. However, at a distance of 10 cm, the E field was less than 75 V/m for all the sealers, at 15 cm the H field was greater than 0.32 A/m for only 4 devices, with a maximum recorded of 0.76 A/m. At a distance of 30 cm the intensities of the electric field and the magnetic field were below the meter's sensitivity for all units.

The Operator Exposure

The field intensities in the vicinity of the operator were measured at 15 cm from the operator toward the applicator. The operator was positioned in the normal working position, closest to the device. Thus, the readings can be considered as upper exposure limits for typical operating conditions. The complete set of results is given in Appendix C, and a summary in Table 4. It should be noted that, for the sewing machine type of sealers the results for exposure of the operator's hands are not included in Table 4. This information can be obtained from the fields in the vicinity of the applicator, Figures 6 - 9 and Appendix B.

Table 5 shows the number of devices for each type of RF heater, whose operators are exposed to the electric or magnetic fields with equivalent power densities greater than 5 mW/cm^2.

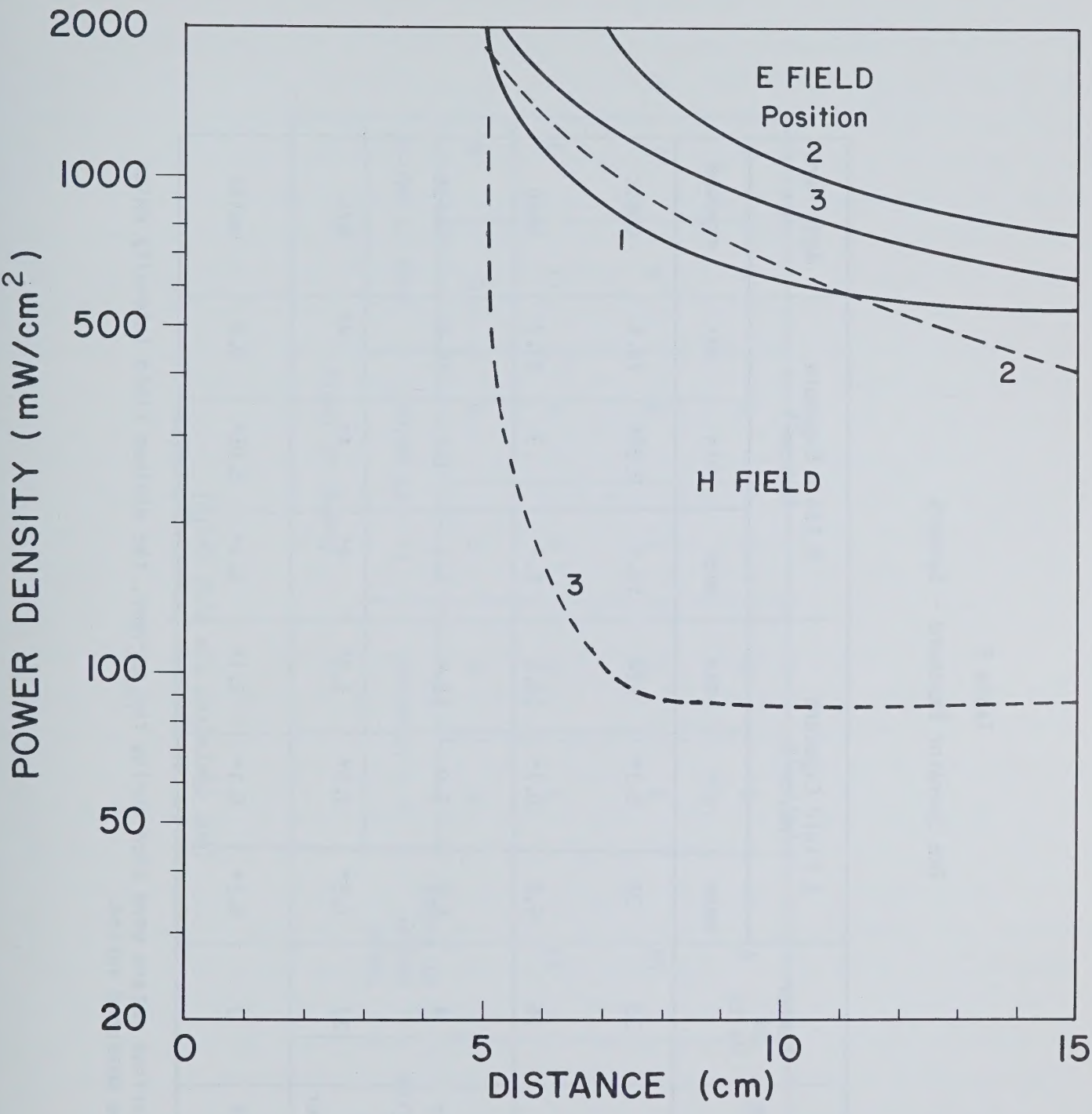


FIGURE 10. Electric and Magnetic Field in the Vicinity of Shuttle Tray Sealer

Table 3

The Operator Exposure - Summary

RF Heater Type	Number of Units	E Field Exposure (mW/cm^2)			H Field Exposure (mW/cm^2)			Body Part max
		mean	min	max	mean	min	max	exposed
Sewing Machine	33	28	0.1*	124	10.9	0.05*	74.4	chest
Shuttle Tray	16	6.2	0.1*	18.6	4.7	9	27.7	head
Turntable	4	5.2	1.9	11.8	5.1	1.0	15.0	waist
Pressure Sealed Applicator	21	1.5*	1.5*	1.5*	4*	4*	4*	N/A
Edge Glue Dryer	7	0.1*	0.1*	0.1*	0.1*	0.05*	0.8	waist

* Since various meters were used during the surveys, the minimum field intensity which could be measured varied.

Table 4

Exposure to the Operator Exceeding 5 mW/cm
(not corrected for duty cycle)

Sealer Type	Total Number of Units	Number of Units					
		5 - 10 mW/cm^2		11 - 25 mW/cm^2		Over 25 mW/cm^2	
		E	H	E	H	E	H
Sewing Machine	33	3	6	5	5	11	3
Shuttle Tray	16	6	1	1	3	0	1
Turntable	4	0	0	1	1	0	0

DISCUSSION OF THE SURVEY RESULTS

The intensity of the electric and magnetic fields in the vicinity of several RF sealers, measured with the operator as far as possible (at least 0.5 m) from the applicator, was found to decrease with the distance from the applicator. Although some deviations from this trend were observed, it was found that the equivalent power density of the fields decreases approximately inversely proportionally with the distance (power density ~ 1/distance), for distance between 5 to 15 cm from applicator. For the sewing machine type sealers, relatively large differences between the mean values of the fields at the three positions were observed (Figure 6). This is attributed to the uncertainties in measuring the fields, due to the calibration accuracy (±0.5 dB), the non-isotropic response of the probe, and perturbation of the field by the handle, nearby objects, the surveyor and the machine operator. For some sealers, relatively large differences existed in the field intensities at various positions along the applicator at the same distance from it. This might have been caused by asymmetries of the applicator (die) or the variations in the perturbed field. However, in most cases the variations are within the estimated uncertainty of ±3 dB (Figures 7-9).

Apart from sewing machine and pressure sealed applicator devices insufficient data for analysis was obtained for other types of applicators. The data in Figure 10 represents only one shuttle tray device. Further discussion is therefore limited to these two types of sealers for which sufficient data was obtained.

For short distances from the applicator (less than 15 cm) of sewing machine sealers, the ratio of the electric to magnetic field intensity is usually greater than the characteristic impendance of free space (377Ω). Knowing the E/H ratios (equivalent characteristic impendance) may be useful in determining the energy deposited in the body of the operator. It is also clear that, where exposures take place close to the applicator, as in sewing machine type sealers, an underestimate or an overestimate of the actual exposure frequently takes place, if only one field intensity (E or H) is monitored. If the E field equivalent power density is taken as a measure of exposure one overestimates the actual exposure, and vice versa for the H field.

The field intensities at a distance of 5 cm from the applicator of the pressure sealed type devices were generally low, below 75 V/m and 0.32 A/m. Greater field intensities were measured in some positions for a few sealers, but they may be attributed to discontinuities in the seal of the applicator. The maximum H field

intensity was 3.8 A/m for one sealer at 5 cm from the applicator, (Table B 5(a)) which decreased to below 0.32 A/m at 10 cm. The typical H field intensity for these units (12 out of 21) was about 0.7 A/m. The maximum intensity of the electric field was 170 V/m at 5 cm from the applicator. At 15 cm from the applicator, the maximum field intensity was less than 75 V/m (Table B 5(b)).

Operator exposure from RF sealers has been measured by Conover et al [4, 5]. For nine RF plastic sealers, field intensities from 20 to 1000 V/m (equivalent power density from 0.1 to 270 mW/cm^2) and from 0.02 to 13.8 A/m (equivalent power density from 0.15 to 7200 mW/cm^2) were measured [4]. One edge glue dryer surveyed had fields at the operator's position of 230 V/m and 1.05 A/m. Not a single device had both of the fields below the equivalent power density of 10 mW/cm^2 [4]. In the other report [5], it was indicated that the maximum fields recorded were 1000 V/m (270 mW/cm^2) and 2 A/m (150 mW/cm^2). It should be noted, that all the field intensities reported above refer to the intensities when the RF power is on, not averaged over any period of time. When the exposure fields were corrected for the duty cycle, 60% of the surveyed units exceeded 200 V/m (10 mW/cm^2) and 29% exceeded 0.5 A/m (10 mW/cm^2) [5].

During this survey the RF fields in the vicinity of the operator were measured for 33 sewing machine type sealers, 16 shuttle trays, 4 turntables, 21 pressure sealed applicators, and 7 edge glue dryer devices. The maximum intensities recorded for any part of the operator's body, except the hands, were 680 V/m (125 mW/cm^2) and 1.4 A/m (75 mW/cm^2) (Table 3). These values are not corrected for duty cycle.

The highest intensities of the RF fields, as well as the greatest number of devices having relatively high intensities, were found for the sewing machine type sealers. It is worth emphasizing that the total RF power output of this sealer type is relatively low. For most sewing machine type sealers, the output power was between 1 and 6 kW, with a few up to 10 kW. No correlation between the power output and measured field intensities could be established. 48% of the sewing machine sealers had a maximum E field intensity (not corrected for the duty cycle) greater than 200 V/m and 24% had a maximum H field intensity greater than 0.5 A/m (Table 4). The hands of the operator are exposed to fields as large as 1 200 V/m and 1.5 A/m (Figure 6). These operators frequently have to hold the material to be sealed during the time the power is on, their hands are only about 10 cm from the applicator.

If the maximum exposure fields are corrected for duty cycle, the percentage of the devices which expose the operator to the fields exceeding the average intensity of 10 mW/cm^2 significantly decreases. This is discussed in more detail in the next section.

The maximum field intensities measured for shuttle tray devices were 265 V/m (18.6 mW/cm^2) and 0.85 A/m (same devices). However, only 6% of the devices had the E field exceeding 200 V/m and 25% had the H field exceed 0.5 A/m. The output power of this type of sealer is between 3 and 15 kW. Operators are exposed to lower field intensities, since they normally stand at greater distances from the applicator.

The sample of turntable sealers is too small (4) to draw meaningful conclusions. However, the greatest exposure was always to the operators located closest to the applicator. When two persons operated the machine, and were stationed at the two positions most remote from the applicator (Figure 4), their exposures were minimal.

The pressure sealed applicator RF sealers and edge glue dryers were found to produce small exposure to the operators (Table 3 and Appendix C).

A maximum equivalent power density of less than 25 mW/cm^2 (i.e., the corresponding E and H field intensities) is considered to be an acceptable occupational exposure [6]. When the maximum equivalent power density is less than 25 mW/cm^2, the machine duty cycle (i.e., the ratio of RF power ON/(ON + OFF) time) has to be incorporated as a factor in computing the average values of the power density.

This survey revealed that 39% of the sewing machine type sealers exposed the the operator to an E or H field whose equivalent power density was greater than 25 mW/cm^2. Over 90% of these sealers delivered an exposure to the operator's hands greater than 25 mW/cm^2 (Appendix B).

When the average duty cycle of 0.09 is used to calculate the exposure, 58% have an electric or magnetic field intensity greater than the equivalent of 1 mW/cm^2 averaged over 1 hour. This percentage includes the units with a power density greater than 25 mW/cm^2. When "a worst case" duty cycle of 0.5 is used, the computed field intensity exceeds the equivalent of 1 mW/cm^2 in 79% of the devices.

Of the 16 shuttle tray sealers surveyed, only 1 exposed the operator to fields greater than 25 mW/cm^2. The average duty cycle is 0.20, and the worst case 0.5. Sixty-three percent of these devices exposed the operators to power densities greater than 1 mW/cm^2 for the average duty cycle, and 69% for the worst case duty cycle. However, only 1 unit exceeded 10 mW/cm^2 regardless of the duty cycle.

None of the four turntable units surveyed exceeded 25 mW/cm^2. The average duty cycle for this type of sealer is 0.56, and the worst case is 0.71. Two of the four units produced exposures to at least one operator greater than the time-averaged level of 1 mW/cm^2. None of the units produced averaged exposure greater than 10 mW/cm^2.

The average and worst case duty cycles for the pressure sealed applicator heaters are 0.47 and 0.64, respectively. The limited range of the instruments used during the survey only permitted measurement of exposures to the operator that were less than an equivalent power density of 0.75 mW/cm^2 for the E field and 2 mW/cm^2 for the H field. However, since only slightly higher fields were detected in a few cases, very close (5 cm) to the applicator, it appears that the fields to which the operator is exposed are substantially weaker.

For all edge glue dryers (7 units) the maximum exposure (not time averaged) to the operators was less than 1 mW/cm^2.

Of the 81 RF heaters surveyed, 13 (16%) exceeded a level of 25 mW/cm^2. When the exposure was estimated from the average machine duty cycle, 31 (38%) exceeded 1 mW/cm^2 and 14 (17%) exceeded 10 mW/cm^2.

RECOMMENDATIONS AND CONCLUSIONS

The survey of RF heaters in Canada indicates that there are many types of devices in use, and that some of them may pose a health hazard to operators from exposure to high intensity RF fields. While some types of heaters do not expose the operators to excessive RF fields nearly one half of the "sewing machine" sealers surveyed exceeded the maximum exposure recommended in the federal Safety Code [6]. However, this survey data alone is not sufficiently comprehensive for a conclusive analysis. Since only a limited number of units in some categories (e.g., turntable type) were surveyed, and for others, only one parameter was measured (due to the instrumentation problems), some of the data may not be fully representative.

On the basis of the survey results obtained, the following recommendations can be made.

1. Further surveys should be performed, specifically to include devices of the shuttle tray and turntable types.
2. A study to determine the effect of field perturbations due to the operator's presence should be conducted.
3. Guidelines and/or regulations on performance of RF heaters should be developed to protect the workers from excessive RF exposure.
4. Reliable, accurate and reasonably priced survey instrumentation is needed for monitoring the fields in the vicinity of the devices. This would assist in the development of safe working practices.
5. Research should be carried out to determine the rate of energy deposition in the human body and its biological consequences of exposure in the near-field radiation of an RF sealer.

The biological effects of exposure to RF fields, having relatively low average power densities but very high maximum power densities (e.g., sealers having a low duty cycle) have not received sufficient attention. Until the above problems are solved, there would be uncertainty in the safety factors incorporated into any performance standard developed for RF heaters.

REFERENCES

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3. C.H. Durney et. al., Radiofrequency Radiation Dosimetry Handbook, Second Edition, Report SAM-TR 78-22, USAF School of Aerospace Medicine, Brooks Air Force Base, Texas 78235, May 1978.

4. D.L. Conover et. al., Measurement of Electric and Magnetic Field Strengths from Industrial Radiofrequency (15-40.68 MHz) Power Sources, in Biological Effects of Electromagnetic Waves, HEW Publication (FDA) 77-8011, pp. 356-362, 1977.

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6. Health and Welfare Canada. Safety Code-6. Recommended Safety Procedures for the Installation and Use of Radiofrequency and Microwave Devices in the Frequency Range 10 MHz - 300 GHz. 79-EHD-30, February 1979.

APPENDIX A

Table A1 - Plants Surveyed

PROVINCE	PLANT LOCATION	NO. OF HEATERS SURVEYED
Alberta	Cutter Ltd. 8241 - 30th Street South East Calgary	3
	Northwest Tent & Awning Co. Ltd. 10265 - 107th Street Edmonton	1
	Ring Binder & Vinyl Products Ltd. (Western) 14562 - 121st Avenue Edmonton	3
British Columbia	Balic Wood Working Co. Ltd. 2829 Norland Avenue Burnaby	1
	Classic Vinyl & Plastics Ltd. 12187 Industrial Avenue Surrey	3
	Fitz-Wright Mfg Surrey	1
	Kayline Industries Ltd. 12277 - 116th Avenue Surrey	1
	Montalco Kitchen Cabinets Ltd. 12500 Vickers Way Richmond	1
	Port Coquitlam Senior Secondary School 3550 Wellington Street Port Coquitlam	1

PROVINCE	PLANT LOCATION	NO. OF HEATERS SURVEYED
Biritsh Columbia	Rickwell Woodworking 9120 Van Horne Way Richmond	1
	Sauder Manufacturing Ltd. Tru-Fit Division 5776 Beresford Street Burnaby	1
	Scali Durante Furniture Manufacture Ltd. 5371 Regent Street Burnaby	1
	Weldwood of Canada Ltd. 900E Kent Avenue Vancouver	1
Manitoba	Plastic Film Lektroseal Ltd. 114 Market Avenue East Winnipeg	6
Ontario	Chrysler Canada Ltd. Ajax	21
	Methot Sales Ltd. 1373 Ogilvie Road Ottawa	1
	Reel Assessment Workshop 5226 General Road Unit 1 Mississauga	2
	Rolph-Clark-Stone Packaging 300 Orenda Road Brampton	1
	Safeco Manufacturing Ltd. 947 Warden Avenue Scarborough	14

PROVINCE	PLANT LOCATION	NO. OF HEATERS SURVEYED
Ontario	Vicraft Plastics Ltd. 1692 Midland Avenue Scarborough	7
	Weldo Plastics Ltd. 181 Bridgeland Avenue Toronto	10
Quebec	Alcan Plant Princeville	1

Table A2 - RF Heater - Equipment Types - Surveyed

MANUFACTURER	MODEL	FREQUENCY (MHz)	POWER (kW)
Callana	35	27	3.5
Canadian General Tower	-	27.12	1.2
Colpitt	Type 145	27	10
Cosmos	3000	27	3
Cosmos	6000	27.12	6
Cosmos	30,000	20	10
Cosmos	15-2000	27.12	15
ERZ	SB-100	3-7	20
Inpak	M3A	49	1.0
Inpak	RT-72D	27.12	3.5
Inpak	RT 500	27.12	5.0
Kabar	DH 6500 FS	27.12	6.5
L & L Machinery	GA 43-II	5	5
L & L Machinery	GA-43	5	3
L & L Machinery	GA-43-2(1973)	5	3
Mann & Russell	400	13.56	
Newman & Whitney	Raytherm PM 88	4.7	20
Nichols	-	27.12	-
Nichols	E 125 A	32	.750
Raydyne	-	13-20	10
Rye	RF4. 1/3	13.56	4
Sealomatic	300	20-30	3
Sealomatic	300	20-30	3
Sealomatic	600 FS 40	27.12	6
Sealomatic	600 FS 40	27.12	6
Sealomatic	600 FS 40	27	6
Sealomatic	600 SP	20-30	6

MANUFACTURER	MODEL	FREQUENCY (MHz)	POWER (kW)
Sealomatic	120 HPD	40.15	1.2
Sealomatic	1000 FS 40	27	10
Sealomatic	1000 FS 40	27	10
Sealomatic	1200	20-30	12
Sealomatic	600	20-30	6
Seidensha	KB 6000 T	27.12	7
Solidyne	HFE-300	45-50	-
Thermatron	ACME4 AC 335	46	3.0
Thermatron	ACME4 AC 335	46	3.0
Thermatron	ACME4 AC 335	51	3.0
Thermatron	ACME4 AC 335	51	3.0
Thermatron	ACME4 AC 335	51	3.0
Thermatron	ACME4 AC 335	51	3.0
Thermatron	ACME4 AC 335	51	3.0
Thermatron	ACME4 AC 335	51	3.0
Thermatron	ACME4 AC 335	51	3.0
Thermatron	K 0103	25	10
Thermatron	K 103	25	10
Thermatron	KC 103/ASS	25	10
Thermatron	KFC 151	27.12	15
Thermatron	FI-8	27.12	1
Thermatron	P 20	27.12	6
Thermatron	P 23	27.12	-
Thermatron	P 25	25	10
Thermatron	P 25	30	6.0
Thermatron	P 25	30	6.0
Thermatron	P 25	27.12	6.0
Thermatron	P 25 .30	27.12	10
Thermatron	P 25 64	30	6.0

MANUFACTURER	MODEL	FREQUENCY (MHz)	POWER (kW)
Thermatron/Solidyne	P 25 KC 103	25	10.0
Thermex	10 kW	13.56	10
Thermex	10 kW	13.56	10
Thermex	10 kW	13.56	10
Thermex	10 kW	13.56	10
Thermex	10 kW	13.56	10
Thermex	10 kW	13.56	10
Thermex	10 kW	13.56	10
Thermex	10 kW	13.56	10
Thermex	10 kW	13.56	10
Thermex	20 kW	27.12	20
Thermex	20 kW	27.12	20
Thermex	20 kW	27.12	20
Thermex	20 kW	27.12	20
Thermex	90 kW	17-28	90
Thermex	90 kW	17-28	90
Thermex	90 kW	17-28	90
Thermex	90 kW	17-28	90
Thermex	90 kW	17-28	90
Thermex	90 kW	17-28	90
Thermex	90 kW	17-28	90
Thermo-Dielectric	6000	25	6
Thermo-Dielectric	6000	27.12	6
Work Rite	1500	27.1	-
Yamoto	YVS 5000	27.12	5
Unindentified	-		3

Table A3 - RF Heaters - Equipment Types - Unsurveyed

MANUFACTURER	MODEL	FREQUENCY (MHz)	POWER (kW)
Acme	3	49	2
Acme	4 (5 units)	51	3
Colpitt	10,000 (4 units)	27	10
Compo	-	27	20
Herfurth	HP 2000 N (4 units)	35	2
Inpak	M3B	49	3.7
Kabar	6500 FS (4 units)	27.12	6.5
Kabar	10,000 FS (7 units)	27.12	10
Kabar	15,000	27.12	10
Nichols	- (2 units)	-	6
Nichols	E-1505 (2 units)	-	6
Nichols	E-159 (2 units)	-	3
Radio Heaters	PW 4-45	27.12	6
Radyne	- (2 units)	13-20	10
Radyne	FW4A	-	-
Radyne	PW 4	-	3
Radyne	15 CW 150	-	-
Radyne	28 CW 50 (4 units)	-	-
Sealomatic	- (2 units)	-	-
Sealomatic	120 SP (2 units)	40	1.2
Sealomatic	330 (3 units)	20-30	3
Sealomatic	400	27.12	4
Sealomatic	500	25-30	5
Sealomatic	600	27.12	6
Sealomatic	800	20-30	8
Thermatron	AC 17	50	7
Thermatron	AC 335 (3 units)	51	3

MANUFACTURER	MODEL	FREQUENCY (MHz)	POWER (kW)
Thermatron	K 325	30	3
Thermatron	K 415 (3 units)	30	
Thermatron	K 625	23.46	6
Thermatron	K 645 A		
Thermatron	K 103 SA	25	10
Thermatron	KC 33	30	3
Thermatron	KC 41	30	4
Thermatron	R-25	30	-
Thermatron	KC 64 (4 units)	30	6
Thermatron	KC 103 (2 units)	25	10
Thermatron	P 20	30	6
Thermatron	P 23	-	-
Thermatron	P 25 (2 units)	25-26	6
Thermex	(2 units)	-	20
Thermex	10 H4B (9 units)	13-15	10
Thermex	30 HA 142 (2 units)	13-27	30
Thermex	T 500 SA 339 (7 units)	17-28	60
Yamamato	5,000	40.69	5
Unknown	4 units	-	-

APPENDIX B

Fields in the Vicinity of the Applicator for Selected RF Sealers

The designation of the measurement positions for the devices is shown in Figures B1 to B3. The data for the sewing type sealers is summarized in Tables B1 to B3, while the data for other sealers is given in Tables B4 and B5. All the field intensities are expressed in the equivalent plane-wave power density.

Table B1

Sewing machine type sealers. Field intensities expressed in the equivalent power density units 5 cm from the applicator

Unit No.	P (kW)	f (MHz)	POSITION 1		POSITION 2		POSITION 3	
			E(mW/cm^2)	H(mW/cm^2)	E(mW/cm^2)	H(mW/cm^2)	E(mW/cm^2)	H(mW/cm^2)
2	1.2	27.12	2170	1293	>2480	3325	>2480	9237
9	1.0	49	202	831	808	665	202	41
18	-	27.12	1240	44	1612	222	806	222
19	.750	32	744	19	1054	33	1364	19
28	1.2	40.15	1155	44	770	52	825	41
32	6.0	20-30	1984	240	>2480	185	2046	370
35	3.0	46	620	25	74	9	496	26
36	3.0	46	1890	129	1680	120	1680	19
37	3.0	51	450	1663	450	1293	1600	1478
38	3.0	51	1300	59	700	56	1100	56
39	3.0	51	800	1293	2000	1108	1500	739
40	3.0	51	400	11	150	13	170	11
41	3.0	51	1700	111	>2000	388	1300	--
42	3.0	51	1262	1108	1868	4803	>2020	9237
50	-	27.12	1736	92	1426	129	>2480	56
56	6.0	30	744	--	1240	--	1302	--
55	10.0	27.12	1736	259	>2480	129	>2480	406
Max	10.0	49	2170	1663	2480	4803	>2480	9237
Min	.750	27.12	202	11	74	9	170	11
$\underline{n}$	15	17	17	16	13	16	13	15
$\bar{x}$	3.3	39.9	1184	451	1064	783	1107	1464
SD	$\pm$2.4	$\pm$11.4	$\pm$611	$\pm$574	>635	$\pm$1365	$\pm$577	$\pm$3180

Table B2

Sewing machine type sealers. Field intensities expressed in the equivalent power density units 10 cm from the applicator

Unit No.	P (kW)	f (MHz)	POSITION 1		POSITION 2		POSITION 3	
			E(mW/cm^2)	H(mW/cm^2)	E(mW/cm^2)	H(mW/cm^2)	E(mW/cm^2)	H(mW/cm^2)
2	1.2	27.12	550	590	900	825	750	660
9	1.0	49	13	100	38	111	38	30
18	-	27.12	248	6	590	20	434	34
19	.750	32	155	6	197	8	91	9
28	1.2	40.15	98	7	190	6	120	6
32	6.0	20-30	490	56	270	37	285	97
35	3.0	46	41	< 4	17	< 4	80	< 4
36	3.0	46	240	28	600	34	240	17
37	3.0	51	145	150	450	170	190	175
38	3.0	51	670	7	320	6	285	6
39	3.0	51	250	315	450	135	250	210
40	3.0	51	20	< 4	38	< 4	57	< 4
41	3.0	51	640	4	625	12	540	16
42	3.0	51	135	505	470	558	395	590
50	-	27.12	315	25	270	25	350	14
56	6.0	30	450		600		250	
55	10.0	27.12	775	66	890	47	415	118
Max	10.0	49	775	590	900	825	434	660
Min	.750	27.12	13	< 4	17	< 4	57	< 4
n	15	17	17	14	17	14	17	14
$\bar{x}$	3.3	39.9	308	133	407	142.4	281	142
SD	±2.4	±11.4	±243	±195	±274	±244	±189	±216

Table B3

Sewing machine type sealers. Field intensities expressed in the equivalent power density units 15 cm from the applicator

Unit No.	P (kW)	f (MHz)	POSITION 1		POSITION 2		POSITION 3	
			E(mW/cm^2)	H(mW/cm^2)	E(mW/cm^2)	H(mW/cm^2)	E(mW/cm^2)	H(mW/cm^2)
2	1.2	27.12	434	536	372	499	372	406
9	1.0	49	-	-	-	-	-	-
18	-	27.12	155	15	403	7	434	26
19	.750	32	37	<4	43	4	31	4
28	1.2	40.15	55	6	149	4	182	6
32	6.0	20-30	217	33	124	24	124	30
35	3.0	46	12	<4	12	<4	25	<4
36	3.0	46	153	22	368	22	105	13
37	3.0	51	100	111	200	56	100	92
38	3.0	51	200	<4	100	4	100	4
39	3.0	51	100	148	250	46	150	148
40	3.0	51	15	<4	20	<4	15	<4
41	3.0	51	200	4	250	7	200	5
42	3.0	51	51	148	202	406	202	148
50	-	27.12	124	22	167	15	161	13
56	6.0	30	744	-	1178	-	186	-
55	10.0	27.12	620	48	558	37	310	74
Max	10.0	49	740	536	558	499	434	406
Min	.750	27.12	12.4	<4	12	<4	15	<4
n	15	17	16	13	16	13	16	13
$\bar{x}$	3.3	39.9	201	85	275	87	169	75
SD	±2.4	±11.4	±215	±146	±284	±164	±119	±113

Table B4

Field intensities, expressed in the equivalent power density units, in the vicinity of Shuttle Tray and Turntable Types of RF Sealers (E & H Fields mW/cm^2)

SHUTTLE TRAY APPLICATOR

Unit No.	P (kW)	f (MHz)	Distance (cm)	POSITION 1		POSITION 2		POSITION 3	
				E	H	E	H	E	H
12	6.5	27.12	5	2480	5172	>2480	1847	2232	1293
			10	660	2180	1275	690	910	92
			15	560	1720	890	415	630	92

TURNTABLE APPLICATOR

Unit No.	P (kW)	f (MHz)	Distance (cm)	POSITION									
				1		2	3	4	5	6	7	8	9
				E	H	E	E	E	E	E	E	E	E
49	6.0	27.12	5	1612	9237	2232	2176	2232	>2480	>2480	>2480	>2480	2232
			10	390		480	460	690	870	540	1100	1000	496
			15	249		200	255	257	500	315	700	745	496

Table B5(a)

PRESSURE SEALED APPLICATORS DISTANCE = 5.0 cm
All field intensities expressed in the equivalent power density - mW/cm^2

Unit No.	P (kW)	f (MHz)	POSITION 1		POSITION 2		POSITION 3		POSITION 4		POSITION 5		POSITION 6	
			E	H	E	H	E	H	E	H	E	H	E	H
20	10	13.56	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
58	10	13.56	<1.5	12	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	4	<1.5	<4
59	10	13.56	<1.5	10	<1.5	10	<1.5	10	<1.5	<4	<1.5	31	<1.5	101
60	10	13.56	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
61	10	13.56	<1.5	<4	<1.5	<4	<1.5	<4	10	16	3	16	3	20
62	10	13.56	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	8	8	20	2	27
63	10	13.56	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	58	<1.5	8
64	10	13.56	<1.5	<4	<1.5	<4	<1.5	16	<1.5	<4	<1.5	<4	<1.5	<4
65	10	13.56	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
66	10	13.56	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	8	<1.5	<4	<1.5	<4
67	20	27.12	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
68	20	27.12	<1.5	19	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
69	20	27.12	<1.5	<4	<1.5	37	<1.5	13	<1.5	<4	<1.5	<4	<1.5	<4
70	20	27.12	<1.5	19	<1.5	41	7	554	<1.5	<4	<1.5	19	<1.5	19
71	90	17-28	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
72	90	17-28	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
73	90	17-28	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
74	90	17-28	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
75	90	17-28	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
76	90	17-28	<1.5	<4	<1.5	13	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
77	90	17-28	<1.5	295.6	<1.5	148	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
Min			<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
Max			<1.5	295.6	<1.5	148	7	554	10	16	8	58	3	101
n			21	5	21	5	1	4	1	3	2	6	2	5
x			<1.5	71.1	<1.5	49.8	7	148.2	10	10.7	5.5	24.7	2.5	35
SD				±125.6		±56.6		±270.5		4.3	±3.5	±18.5	±0.7	±37.5

Table B5(b)

PRESSURE SEALED APPLICATORS DISTANCE = 15 cm

Unit No.	P (kW)	f (MHz)	POSITION 1		POSITION 2		POSITION 3		POSITION 4		POSITION 5		POSITION 6	
			E	H	E	H	E	H	E	H	E	H	E	H
20	10	13-20	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
58	10	13.56	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
59	10	13.56	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
60	10	13.56	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
61	10	13.56	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	6	<1.5	10
62	10	13.56	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	6
63	10	13.56	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
64	10	13.56	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
65	10	13.56	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
66	10	13.56	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
67	20	27.12	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
68	20	27.12	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
69	20	27.12	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
70	20	27.12	<1.5	<4	<1.5	13	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
71	90	17-28	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
72	90	17-28	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
73	90	17-28	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
74	90	17-28	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
75	90	17-28	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
76	90	17-28	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
77	90	17-28	<1.5	<4	<1.5	11	<1.5	22	<1.5	<4	<1.5	<4	<1.5	<4
Min			<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4	<1.5	<4
Max			<1.5	<4	<1.5	13	<1.5	22	<1.5	<4	<1.5	6	<1.5	10
$\underline{n}$			21	21	21	2	21	1	21	21	21	1	21	2
$\bar{x}$			<1.5	4	<1.5	12	<1.5	22	<1.5	<4	<1.5	6		8
SD				<4		±1.4								±2.8

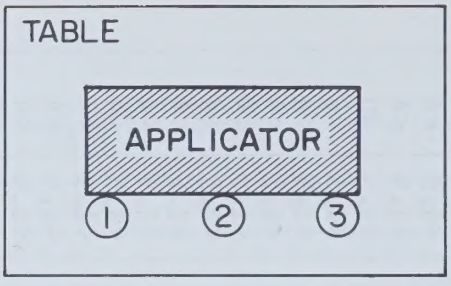

Fig. B1-Sewing Machine Sealer- Measurement Positions

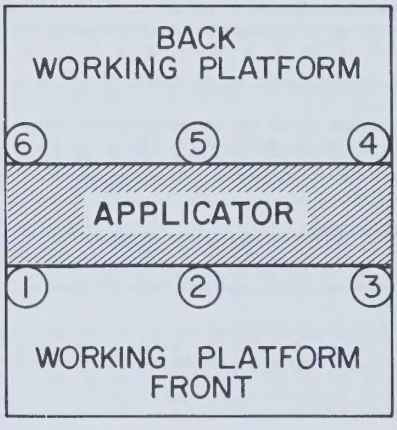

Fig. B2-High Pressure Sealers-Measurement Positions

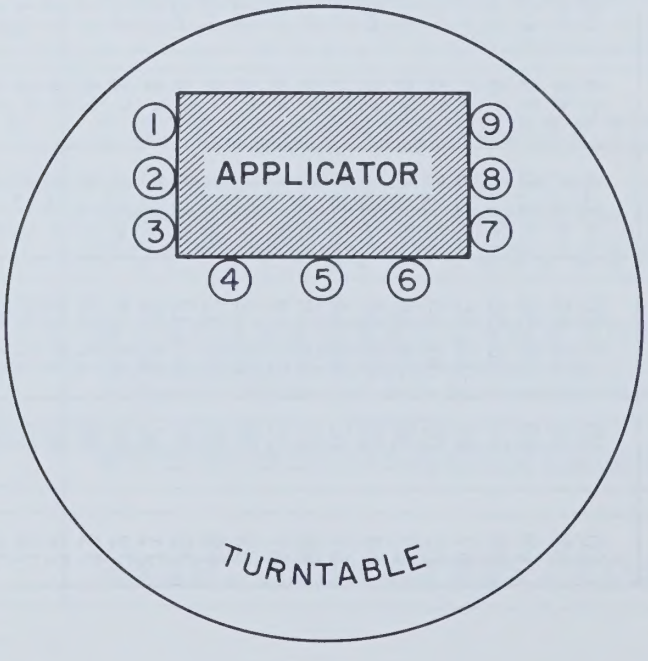

Fig. B3-Turntable Sealers-Measurement Positions

APPENDIX C

The Operator Exposure, Complete Survey Data

The survey data grouped by the device type is shown in Tables C1, C2, C3, C4 and C5 for the sewing machine, shuttle tray, turntable, pressure sealed type and for the edge glue dryers, respectively. All field intensities are reported in the equivalent power densities.

TABLE C1

Sewing machine type RF sealers, the operator exposure; the field intensities (E and H) given in the equivalent power density units (mW/cm^2)

Unit No.	P (kW)	f (MHz)	Chest		Waist		Head	
			E	H	E	H	E	H
2	1.2	27.12	5.0	51.7			22.3	14.8
6	10.0	27.12		1.1				
9	1.0	49	<1.5	<4			<1	<4
18	-	27.12	18.6	12.9			18.6	44.3
19	0.75	32	13	<4			5.6	<4
22	3.0	20-30		5				
23	3.0	20-30		<4		<4		<4
24	6.0	27.12	3.0	4.0	6.0		3.0	0.5
27	6.0	27.12						3.2
28	1.2	40.15	1.6	<4			2.2	<4
29	10.0	27		15	64		72	5.0
30	10.0	27	31	7.0	40	10	39	2.0
31	12.0	20-30						8.0
32	6.0	20-30	124	9			93	15
35	3.0	46	<1.5	<4			<1.5	<4
36	3.0	46	42	15			47	11
37	3.0	51	30	8			30	<4
38	3.0	51	15	6			25	<4
39	3.0	51	60	13			60	9
40	3.0	51	<1.5	<4			<1.5	<4
41	3.0	51	15	<4			10	<4
42	3.0	51	51	54			60	37
43	3.0	51		5.0				5.5
46	10.0	25	10	2.5	8.0	2.5	25	2.5
48	1.0	27.12	2.2	1.0	0.6	0.1	6.0	0.2
50	-	27.12	12.4				19	
52	6.0	30		2.0				
53	6.0	30	56				74	
54	6.0	30	5				4.3	
56	6.0	30	124				62	
57	10.0	25		18		5.4		7.2
81	5.0	27.12	4			2.0		4

TABLE C2

Shuttle Tray RF sealer, the operator exposure

Unit No.	Manufacturer	P(kW)	f(MHz)	Number of Operators	Head		Chest		Waist		Gonads	
					$E(\frac{mW}{cm^2})$	$H(\frac{mW}{cm^2})$	$E(\frac{mW}{cm^2})$	$H(\frac{mW}{cm^2})$	$E(\frac{mW}{cm^2})$	$H(\frac{mW}{cm^2})$	$E(\frac{mW}{cm^2})$	$H(\frac{mW}{cm^2})$
1	Callana	3.5	27.0	1	7.2	4.0		4.0		4.0		
3	Colpitt	10.0	27.0	3	8.9	1.0		1.0		1.0		
4	Cosmos	3.0	27.12					1.0				
5	"	6.0	27.12	1		1.0		1.0				
7	"	15.0	27.12	1		3.2	6.7	5.4				10.8
12	Kabar	6.5	27.12	1	18.6	4	18.6	27.7				
33	Seidensha	7.0	27.12	2				0.9				
34	Solidyne	--	45-50	-				0.9				
44	Thermatron	10.0	25.0	2	4.3		7.4					
					5.0		3.7					
45	Thermatron	--	--	2			3.0					
47	Thermatron	15.0	27.12			16.0		16.0				15.0
						2.0						
51	Thermatron	10.0	25.0	2		1.0		1.0		1.0		1.0
						2.0		2.0		2.0		2.0
55	Thermatron	10.0	27.12	2	3.7	<4	5.0	<4				
78	Thermo-Dielectric	6.0	25.0	1	0.2	2.0		1.0		1.0		
79	Thermo-Dielectric	6.0	25.0	1	0.1	4.0	0.1	5.0		2.0		
82	Unknown	3.0	--	-		7.0		17.0				

TABLE C3

Turntable RF sealers, the operator exposure

Unit No.	Manufacturer	P(kW)	f(MHz)	Number of Operators	Head		Chest		Waist	
					$E(\frac{mW}{cm^2})$	$H(\frac{mW}{cm^2})$	$E(\frac{mW}{cm^2})$	$H(\frac{mW}{cm^2})$	$E(\frac{mW}{cm^2})$	$H(\frac{mW}{cm^2})$
10	Inpak	3.5	27.12	2	<1.5					
11	Inpak	-	27.0	2	<1.5					
25	Sealomatic	6.0	27.12	4		1-2*		1-10*		0-15*
49	Thermatron	6.0	27.12	2	2-12*		2.5-7.5*			

* For various operators (different positions).

TABLE C4

Pressure sealed applicator RF sealers, - the operator exposure

Unit No.	Manufacturer	P (kW)	f (MHz)	Maximum Exposure E (mW/cm^2)	H (mW/cm^2)
20	Raydyne	10	13-20		
58	Thermex	10	13.56		
59	"	10	13.56		
60	"	10	13.56		
61	"	10	13.56		
62	"	10	13.56		
63	"	10	13.56		
64	"	10	13.56		
65	"	10	13.56	Less than	Less than
66	"	10	13.56	1.5 mW/cm^2	4 mW/cm^2
67	Thermex	20	27.12		
68	"	20	27.12		
69	"	20	27.12		
70	"	20	27.12		
71	Thermex	90	17-28		
72	"	90	17-28		
73	"	90	17-28		
74	"	90	17-28		
75	"	90	17-28		
76	"	90	17-28		
77	"	90	17-28		

TABLE C5

Edge glue RF dryers, the operator exposure

Unit No.	Manufacturer	P(kW)	f(MHz)	Head		Chest		Waist		Gonads	
				$E(\frac{mW}{cm^2})$	$H(\frac{mW}{cm^2})$	$E(\frac{mW}{cm^2})$	$H(\frac{mW}{cm^2})$	$E(\frac{mW}{cm^2})$	$H(\frac{mW}{cm^2})$	$E(\frac{mW}{cm^2})$	$H(\frac{mW}{cm^2})$
8	ERZ Incorporated	20	4	<0.1	0.5	<0.1	0.5	<0.1	0.5	<0.1	0.5
13	L & L Machinery	5	5	<0.1	<0.05	<0.1	<0.05	<0.1	<0.05	<0.1	<0.05
14 & 15	L & L Machinery	3	5	<0.1	<0.05	<0.1	<0.05	<0.1	<0.05	<0.1	<0.05
16	Mann Russell		13.56	<0.1	0.3	<0.15	0.4	<0.1	0.15	<0.1	0.25
18	Newman & Whitney	20	4-7	<0.1	0.1	<0.1	0.1	<0.1	0.1	<0.1	0.1
21	Pye Thermal Bonders	4	13.56	<0.1	<0.05	<0.1	<0.05	<0.1	<0.05	<0.1	<0.05

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